JUNE, 1919 BULLETIN 214

University of Vermont and State Agricultural College

Vermont Agricultural Experiment Station

BURLINGTON, VERMONT

TIP BURN OF THE POTATO AND OTHER PLANTS

By B. F. LUTMAN

BURLINGTON
FREE PRESS PRINTING CO.
1919.

☞Copies of the reports and bulletins of the Station are sent free of charge to any address upon application.

☞Address all communications concerning station matters not to individual officers but to the Experiment Station, Burlington, Vt. Address inquiries concerning farm practice to Extension Service, Burlington, Vt.

Director's office, chemical, horticultural and dairy laboratories are in Morrill Hall at the head of Main street; botanical and bacteriological laboratories are at Williams Science Hall, University Place; veterinary laboratories are at 499 Main street. University farm and buildings are on the Williston road, adjoining the University grounds on the east.

PLATE I.—Figure 1. Potato leaf showing bad attack of tip burn. Some early blight spots fuse with the tip burn areas while others are distinct in the middle of the leaflets. Figures 2, 3, 4, 5. Leaflets affected by tip burn; any portion of the leaflet may be injured. Figure 6. Potato branch taken from the field, August 17, 1917. Leaves from this branch are shown in text figure 4. Figure 7. Typical branch of potato plant just before blossoming. The upright position of the leaflets in the centre of the branch should be compared with the drooping, middle sized and older leaves.

PLATE II.—Figure 1. Tomato leaves showing tip burn during the summer of 1915. Figures 2 and 3. Bean leaves in same summer.

BULLETIN 214: TIP BURN OF THE POTATO AND OTHER PLANTS

By B. F. Lutman

SUMMARY

1. Tip burn of the potato is due to excessive heat and sunshine during late July and early August. An inordinate transpiration from portions of the leaflets directly affected results in a wilting from which the parts seriously injured do not recover.

2. The advance of the tip burn only occurs on hot brilliant days. During cloudy or cool weather it makes no progress.

3. Tip burn can be simulated in the greenhouse even in early spring by directing an excess of sunlight on any portion of the potato foliage.

4. The high osmotic pressure of the sap of the stalks of the plants as compared to that from the leaves undoubtedly aggravates this disease.

5. Tip burn may be largely prevented by shading and to some extent by the application of bordeaux mixture.

6. Early varieties are affected sooner and more seriously than late ones. The foliage of the latter often largely survives the weather producing tip burn and renews growth in September.

7. The removal of from 30 to 40 percent of the foliage by tip burn is not at all uncommon during July and August and even more than this is often lost by September 1.

INTRODUCTION

The lack of light seems to have impressed many students of plant diseases. Sorauer devotes a generous section in his "Handbook of Plant Diseases" (14) to this subject whereas all he has to say touching an excess of light is confined to three pages; indeed he does not deem the latter injury important enough to mention in his yearly summaries of plant diseases in Just's Jahresberichte. This will not seem strange to us when we remember that the study of plant pathology has been developed largely under European influence, and that under the northern European conditions with which these scientists were best acquainted it is undoubtedly true that lack of light is of more importance than excess of light. Owing to the high latitudes of these countries the sunshine is much weaker. Then, too, the peculiar atmospheric conditions produce a hazy, humid air. Clear, brilliant sunshine such as occurs during so many summer days in the North American forties is a rarity. The tropics ought to furnish many instances of injury to plants by excessive sunlight but the attention of plant pathologists does not seem to have been attracted to any extent in this direction, although Ewart (3) has made some interesting observations.

The acre production of potatoes in the United States is slightly less than 100 bushels whereas in Germany and England it is over 200 bushels. This lowered yield is due to a considerable extent to poor seed, improper cultivation, etc., but tip burn, on the whole, is the most important single limiting factor, except the Colorado potato beetle and the late blight. The extent to which the growing season is shortened and the amount of foliage is destroyed by tip burn, especially on the lighter soils and in the warmer portions of this country, is not likely to be appreciated, unless one actually spreads out the leaves and computes the destroyed areas.

The brilliancy of the sunshine during some parts of summer days in the temperate regions must almost approach that of the tropics. To be sure its intensity is not maintained for as long a period of time but it must be remembered that protracted exposure of foliage is not necessary to bring about a serious injury, especially of plants such as the potato cultivated out of their natural habitats. The potato flourishes wild in the shaded valleys of the mountainous regions of South America whence it originated. The air is relatively cool and hazy. The atmospheric conditions in North America during the growing season are in the main favorable to the growth and proper functioning of

the potato foliage, but during certain periods in the summer the light is almost tropical in its intensity and the potato foliage tips are scorched.

The first observations of tip burn in this country were made by Jones in Vermont (8) and Sturgis in Connecticut (16) in connection with studies on the early blight of potatoes. Sturgis (16) quotes a letter received from an extensive grower of potatoes in Pittsburg, Pa., as follows:

"For about six weeks there has been almost no rain; the weather has been very close and the sun hot. Under these conditions many potato fields have been wholly destroyed, those on sandy soil suffering most." Sturgis thinks "that extreme heat and dryness, accentuated by lack of moisture in the soil, may induce the death of tissues at a distance from the roots (the tips and edges of leaflets); that this damage may be increased and even initiated by the attacks of predatory insects (flea-beetles)." Jones (8) describes the disease as "characterized by the death of the potato leaves at their tips and margins, which portions dry, blacken and roll up or break off. This trouble has occurred quite commonly in Vermont during the dry, hot weather of midsummer in 1894 and 1895, and, as before stated, it was observed to a worse degree in Michigan and Wisconsin where the drought was more severe. In its earlier stages the dead tissues are often quite free from invasion by fungi, and even in the advanced stages the fungi present are chiefly saprophytes, i. e., such as live upon dead plant tissue only. It is attributable to the unfavorable conditions surrounding the plant, especially to the hot dry weather with insufficient water supply. It is aggregated by any other conditions which tend to lower the general vigor of the plant, such as insufficient food supply, attacks of insects and the early blight fungus. This difficulty has not been observed to any serious degree upon plants until after they pass the blossoming period, and naturally begin to weaken."

Goff (7) found in the summer of 1894 in Wisconsin that Everett's Heavy Weight, Rural New Yorker No. 2, Green Mountain and Everett's Colossal were very resistant to the heat, while some of the older varieties failed utterly. He suggests that the disease may be due to a reduction in the vigor of the older varieties and to be a symptom of "running out." A lack of moisture in the soil greatly aggravated the affection.

Occasional other references occur, especially in the literature of potato spraying. Lodeman (9) says that "plants grown upon dry

soils, those which are naturally warm and 'quick', are more subject to the disease than those grown in moister places in the same field. * * * * Water seems to be the one thing most needed." Stewart (16) makes frequent reference to this trouble near Geneva, N. Y., and attributes much to the beneficial results obtained from bordeaux spraying in preventing or retarding this disease. Similar results have been obtained at this Station (10) from the use of bordeaux on potatoes. In recent years we do not seem to hear as much of tip burn in potatoes, although Fraser (5) states that in 1913 it was very severe in Quebec, "being favored by the dry weather, decreasing the vitality of the plants." Conservation of moisture and control of insects and fungi by spraying held the disease in check. No mention seems to occur in European literature of a similar disease; however Dr. W. A. Orton of the Federal Bureau of Plant Industry has informed the writer that he observed typical tip burn on the potatoes in Germany during the very dry summer of 1911.

Tip burn usually makes its appearance during late July or early August. The maturity of the plants, soil conditions, variety, preceding weather and growth have something to do with its destructiveness, but the principal factor seems to be heat and the intensity of the light.

Orton (12) in his interesting paper on the environmental influences which affect the health of the potato plant points out the fact that long, cool, equable summers are necessary for heavy potato harvests. The premature ripening of potatoes grown under the hot sun of the Southern States results in tip burn and in tubers which are constitutionally weak. It seems to be impossible to restore this vigor by a transfer to more favorable regions. Erwin (2) has found from a study of the normal temperatures during the growing season at Ames, Iowa, that the maximum was reached in the last ten days in July and that a second high point occurred during the middle of August. The crest of the heat wave is marked also by minimum humidity and maximum possible sunlight. He has found that under these conditions tip burn makes its most rapid progress.

Some authors have attempted to distinguish between tip burn and sun scald. Sun scald occurs when succulent, rapidly growing plants are suddenly subjected to intense sunlight and rapid evaporation. Tip burn is the result of protracted dry heat and hot weather on plants growing on light soil. Galloway's opinion (6) that all of these scaldings and burnings of the leaf are due to essentially the same cause is

undoubtedly the correct one as there are all sorts of intermediate forms.

A Typical Outbreak of Tip Burn on the Potato

A description of a typical scorching of the leaves such as occurred July 20-August 6, 1917, will serve best to introduce this subject. The accompanying weather chart, figure 1, will make clear the rainfall, percentage of humidity, sunshine and maximum temperatures for the time covered by these observations.

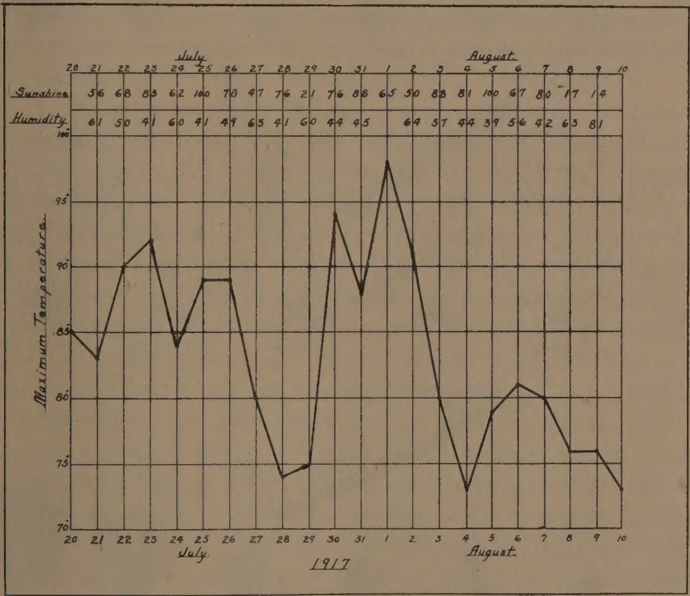

Figure 1.—Chart showing temperature, sunshine and humidity during a tip burn epidemic in late July and early August, 1917.

The weather, prior to July 20, 1917, had been practically normal, plant growth had been rapid and the Green Mountain variety set out about May 20 had nearly finished blossoming. The plants were not unusually large or succulent and a small percentage showed mosaic. July 22 was a very hot day and the effects on the foliage were marked on the following day which was again hot and clear. The advance of the tip burn on these days can be shown best by the figures of leaves drawn on July 23 and July 24 (figure 2). July 24 was much

cooler but sunny and the tip burn areas continued to increase in size; July 25 and July 26 were warm and sunshiny; July 27 was much cooler and cloudy during more than half of the time; and July 28 and 29 were also cool and without much direct sunlight. The advance of the tip burn was checked during the cooler days. The period covered by July

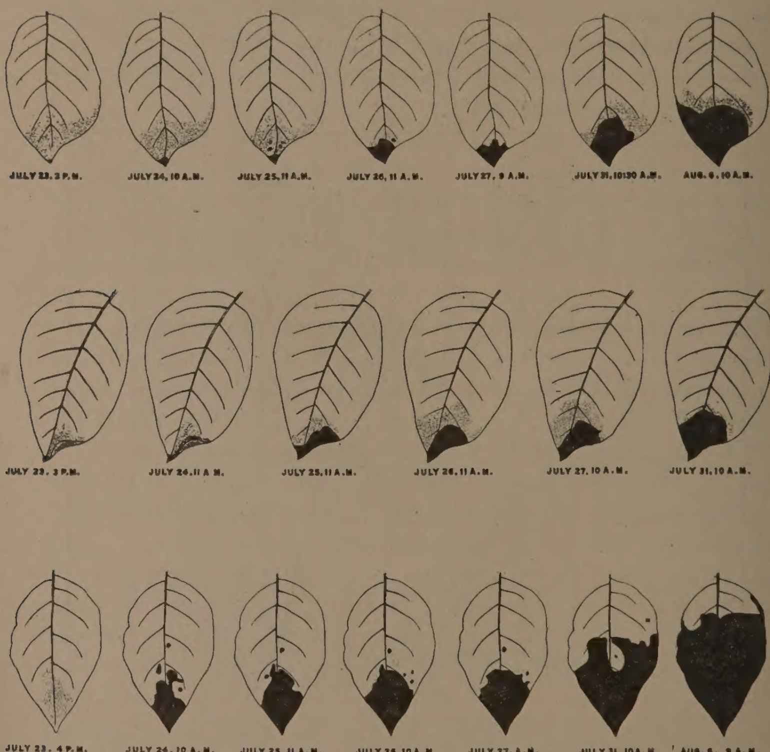

FIGURE 2.—Advance of tip burn on leaflets between July 23 and August 6, 1917.

30, 31, August 1 and 2 was hard on potato foliage and many leaves entirely succumbed to the heat and sunshine. However, the advance of the malady during this latter period was much slower and less marked than during the first one and the drawings do not show the decided daily advance that occurred between July 22 and July 27.

The early stages of tip burn were found on the foliage on the morning of July 23. In most cases these indications were confined to

the ends of the leaflets which in the affected portions were paler than normal and presented a shrivelled or withered appearance. No large part of the leaflet at this time had turned brown. The brown area advanced into this paler portion gradually during the next four days. It was very evident that the leaf tissues had been injured in such a way that they never recovered entirely from the plasmolysis to which they had been subjected. The portion of this withered tissue that was least severely affected might have recovered if the weather subsequently had become more favorable, but the repeated witherings of the succeeding days completed its tissue destruction. The brown, dead portion in this way advanced into and finally covered practically all of the area that after the first unfavorable day had been only pale and withered.

The position of the leaves, as well as their age and maturity, seemed to have much to do with the presence and amount of tip burn. The first five or six very small leaves at the tip of the branches were not attacked but any of the older ones might show tip burn. Plate I, figure 7 sets forth the difference in the position of these leaves. The very young leaves stand upright and are not exposed to the perpendicular rays of the sunshine. The tips of the end leaflets of all the lower ones, however, bend over in such a way that at some time during the day they receive these rays at right angles. The older leaves droop so that not only the tips of the end leaflets are exposed but those of all of the leaflets may hang down and be struck by the tip burn. The oldest leaves are likely to be under the shade of those from the middle of the stem and so suffer less than those in the middle. If they are exposed at all they succumb readily and all of the leaflets die in a few days. The earlier attacks, however, are likely to occur on the middle leaves and after they have become thoroughly scorched and dead, the oldest leaves are exposed and in turn succumb.

The position of the leaves was especially noted during these observations as the amount of tip burn seemed to be dependent on the angle at which the sun's rays struck the end or side of the leaf. The maximum results were produced when the rays fell at right angles to the plane of the leaf. This condition is seen in figure 3. The tips or edges of the leaflets suffered more frequently than the portions of the leaf near its base as they were likely to droop into a position nearly or quite at right angles to the sun's rays. This position was not maintained for any long period of time, never over a few hours, as the

movement of the sun would make the retention of this position-relation very unlikely, but an exposure of even a half hour to an hour was all that was necessary to induce withering and the pallor which preceded browning and death.

FIGURE 3.—Middle leaflet of Figure 2 showing its position in front view (a) and its relation to the rays of the sunlight at about 11 A. M. (b).

These effects did not seem to develop on the plants before nine o'clock as the sunlight does not acquire extreme intensity before that time, but the withering could still be noted after five. The leaves which suffered in the early part of the day were, of course, not the same as those affected in its latter part as the position of the sun brought different parts of the plant under its direct rays. The intense light and heat occurring between eleven and four seemed to produce, as might have been expected, the most severe cases and the most rapid advance of the tip burn.

The fact already noted by Jones (8) that maturity had much to do with the appearance of this disease was emphasized by observations on a plot of Green Mountain potatoes planted a hundred yards away on the same type of soil about a month later than the plot on which the present observations were made. These potatoes were not in blossom during the critical period of July 22-August 2, 1917, and no trace of tip burn was found upon them.

The lack of available potash during the past two or three years appears greatly to have increased the susceptibility of potato plants to tip burn especially if grown on the lighter soils. The plants seem to be

entirely healthy but at the end to be unable to stand up during the trying weather of August. No explanation is offered for this lack of stamina in potash-hungry plants but the observation can easily be made if part of the land has received manure or ashes while another part has received none.

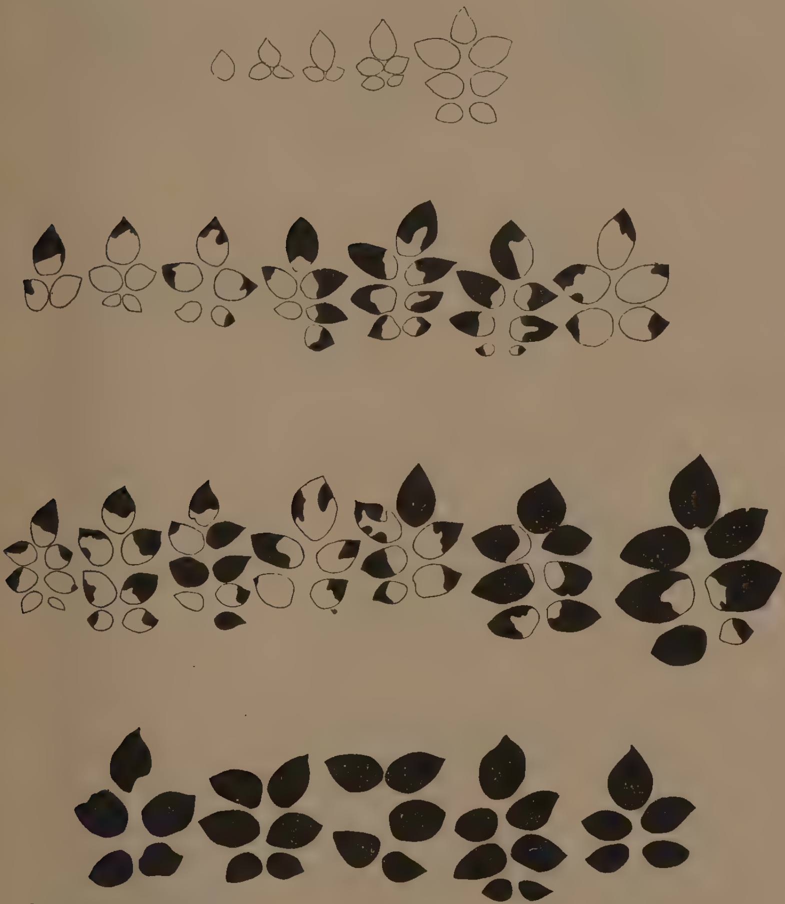

Figure 4.—Branch taken from field on August 17, 1917. The tip burn areas are represented in black.
(a) Leaves all alive.
(b) Leaves partly dead from tip burn.
(c) Leaves all dead from tip burn.

A casual inspection of a field will not reveal the amount of foliage lost from tip burn during an attack of the sort just described. On

August 15, quite a percentage seemed to be lost on a field of Green Mountain potatoes being grown by the local schools. It was thought by some of the school officials that the crop had been struck by late blight and the supervisor of the school plots was roundly taken to task for supposed neglect. No blight, however, was present, but a large percentage of the foliage was dead from tip burn. Three typical branches were removed, the leaves spread out and traced on paper and the area, living and dead, determined by means of a planimeter. The leaflets were divided into three groups:—all dead, all alive and partly dead. The following table gives the areas and percentages on the three stalks:

TABLE I. TIP BURN LOSSES.

	No. I		No. II		No. III	
	Area Sq. In.	%	Area Sq. In.	%	Area Sq. In.	%
Leaves, all alive......	153.42	30.4	79.51	32.3	10.20	4.7
Leaves, all dead......	118.16	23.4	86.93	35.3	46.23	21.4
Leaves, party dead						
dead area.......	68.72	13.6	22.06	8.9	51.13	23.6
live area.......	165.05	32.6	57.79	23.5	108.80	50.3
Total area, alive.....	318.47	63.1	137.3	55.7	119.0	55.0
Total area, dead.....	186.88	36.9	108.99	44.3	97.36	45.0

The drawings of one of the typical branches are shown in figure 4. Almost 40 percent of the total area of the foliage was dead on August 17 from tip burn. It is needless to add that the tuber yield was very small. The plant from which these drawings were made is shown in plate I, figure 6.

A study of a number of leaflets with reference to the position of the venation and the inroads of the tip burn make it plain that no relationship whatever exists between the two. If loss of water were the principal factor in tip burn, it is very evident that the portions of the leaf at the longest distance from the main veins would be first to suffer. The brown areas would extend into the leaf between these veins, whereas as a matter of fact they cut across the veins and veinlets as though they were not present (figure 5). Most of these brown areas occur at the tips of the leaflet and occasionally at the sides but rarely at the base. The browning of a leaflet on the side (plate I, figure 5c and figures 2 and 4), only occurs if this portion is uppermost or is rolled up so as to present it at an appropriate angle to the action of the sunlight.

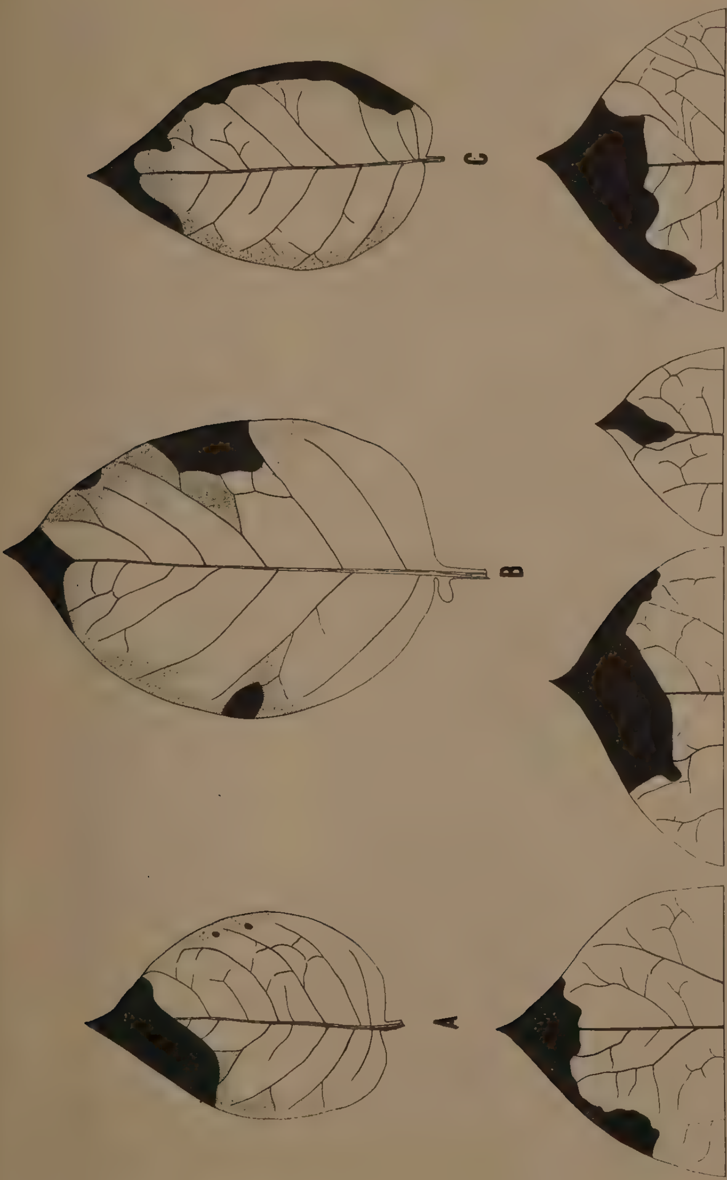

FIGURE 5.—Typical tip burn injuries. It will be noticed that they have no relation to the venation. This fact indicates that the water supply is not the factor of fundamental importance while heat and sunshine are. Leaflets A, B and C were rolled up. The left hand side of A was uppermost and exposed to the sunlight; the two edges of B were rolled together and about equally exposed; the right hand edge of C was rolled so as to be exposed to the sunlight. The leaflets D were not rolled to any extent.

VARIETAL RESISTANCE TO TIP BURN

The early varieties of potatoes are much more susceptible to tip burn than are the later ones; in fact the death of foliage in the former is usually due in this region to severe attacks of tip burn. Our so-called late varieties suffer but they retain enough of their foliage so that they continue growth and tuber formation during September and early October, after the extremely hot weather of August. The yield of tubers is very light from those varieties that tip burn readily. Indeed it is doubtful if it is wise to attempt to raise varieties like Triumph. Other early varieties, such as Early Rose, Early Ohio, Bovee, and Irish Cobbler, lose a considerable part of their foliage but enough leaves remain green and active so that yields are fair, but they never approach those of the standard late Green Mountain, Rural New Yorker or Vermont Gold Coin.

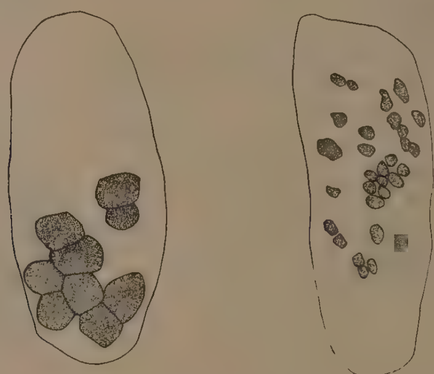

FIGURE 6.—Normal chlorophyl bodies at left; chlorophyl bodies from yellow zone around the tip burn area at the right.

Observations were made during the summers of 1914, 1915 and 1916 on a number of varities grown on light sandy soil. The weather charts for the growing period of these years are shown since a clear understanding of the weather conditions is impossible without them.

RESISTANCE OF POTATO VARIETIES TO TIP BURN IN 1914

At least three periods were observed during which the plants growing in pots were affected by tip burn. The first of these was the week including July 14 and 15. It will be noted on the accompanying chart of maximum temperature (figure 7) that between July 13 and 17

the thermomenter often nearly reached 88° F. These plants continued slowly to die during August. The marked advance in tip

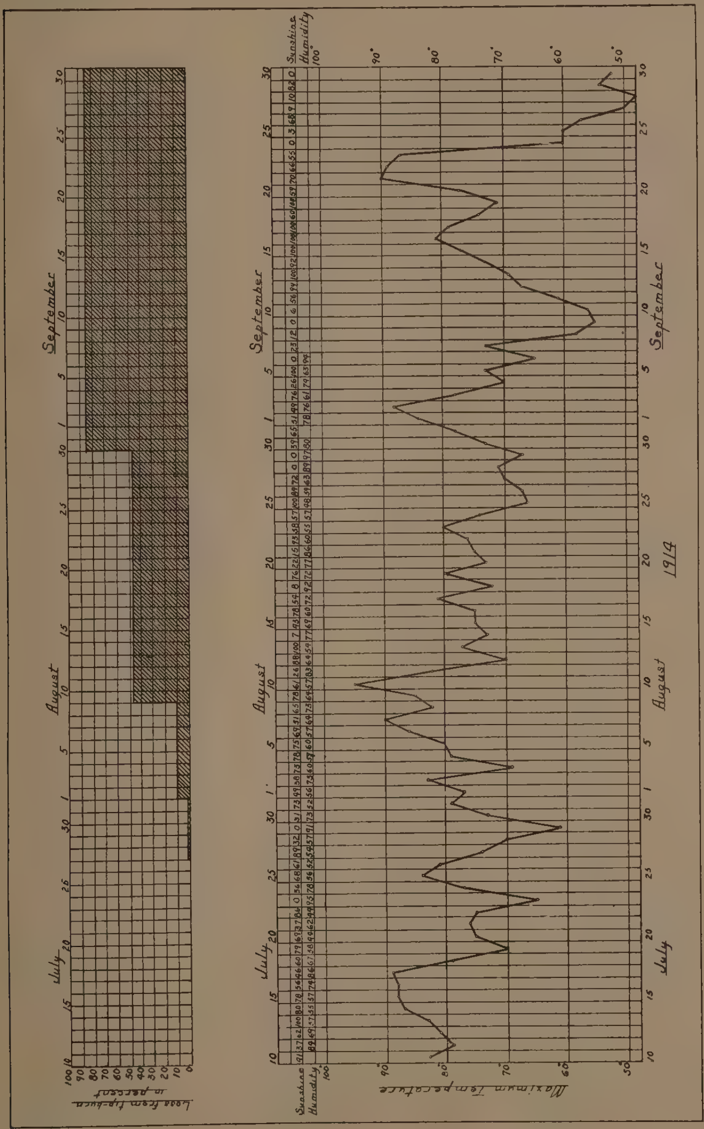

Figure 7.—Chart showing sunshine, humidity and maximum temperatures for 1914.

burn on other plots that were used for spraying experiments oc-

curred during the last week in July. The chart shows that this was a period of very warm weather. On one day in the next period (August 10) the thermometer rose to 94° F. During this time much of the foliage died on the unsprayed plants that were being grown for the study of scab of the lower land. The disease was first noticed on some of the varieties on July 27, although it may have occurred a few days earlier. It was not noted until about the first of September on Green Mountains planted late in June, when the thermometer again rose to 86° F. These observations would seem to point to the conclusion that the onset of the death of the tips was conditioned by two factors, namely, variety and maturity and condition of plants. Early varieties show the trouble before the later ones, but this may be conditioned by the second factor. An examination of the plants beginning to suffer from tip burn showed, in some instances at least, tubers about the size of a hulled walnut. The succulence of the plant also seems to hasten the trouble.

The plants were dusted frequently with paris green and slacked lime but were not sprayed with bordeaux. The land was a light, sandy piece, the east end of which was considerably higher and more exposed to the north and south winds than was the west end. The following table shows the percentage of foliage estimated to have been lost during the warmer part of the summer. The attempt was made to visit the field and make an estimate after each important advance of the tip burn.

TABLE II.—RESISTANCE OF POTATO VARIETIES TO TIP BURN IN 1914.
Percentage of foliage (estimated) dead from tip burn.

Variety	August 1		August 8		August 30	
	West end	East end	West end	East end	West end	East end
Vermont Gold Coin	15-20	20-25	50-60	95	98	99
Irish Cobbler	15-20	15	80-90	80	100	100
Cowhorn	2-5	10	30-40	30-40	98	98
Million Dollar	1-2	2-3	15-20	30-40	90	95
White Ohio	5-10	25-30	80	95	100	100
Cambridge Russet	1-2	5	20-25	50	90	98
Triumph	50-75	50-75	98	100	100	100
Early Ohio	5-10	15	50-60	50	98	99
Dibble's Russet	1	5	10-15	25	40	50
Dakota Red	3-5	3-5	40-50	15-20	50	50
Rural New Yorker No. 2	2-5	2-3	5-10	10-15	50	50
Scab Proof	5-10	3-5	50-60	50	95	95
Twentieth Century	10-15	10-15	80	50	100	99
Beauty of Hebron	10	5-10	20	30-40	90	90
Bovee	10-15	10-15	60	75	100	99

Pride of Vermont	5-10	3-5	30-40	20-25	85	90
Norcross	10	5-10	30-40	30	85	90
Early Rose	15-20	20	40-50	60	99	99
White Star	10-15	5-10	40-50	60	95	98
Burbank's Russet	2-3	5	30-40	30-40	80	98
Canadian varieties*	0	0	0-5	0-5	10-20	10-20

*Planted June 18; Davies' Warrior, Moreton Beauty, etc.

RESISTANCE OF POTATO VARIETIES TO TIP BURN IN 1915

June and early July, 1915, were dry although the drought was not as severe nor as prolonged as that of June, 1914. Abundant rains and saturated atmosphere during the middle of August induced an epidemic of late blight which was checked by the drier weather of late August.

The first tip burn was noted in the week July 25-31. Early Rose, planted early in May in tiles, showed marked tip burn at this date. The several varieties had been planted on the same land on May 20. The weather conditions are shown in the accompanying chart (fig. 8).

TABLE III.—PERCENTAGE OF FOLIAGE ESTIMATED DEAD FROM TIP BURN, SUMMER 1915.

Variety	July 29	Aug. 13	Aug. 23	Sept. 1
Green Mountain	0	0	5	30-40, early blight
Norcross	0	traces	5	30-40, early blight
Rural New Yorker No. 2	0	traces	5	75, early blight
Early Rose	0	15-20 plants yellow	90	100
Irish Cobbler	0	50 plants yellow	100	100
Scab Proof	0	traces	10-15	60
Beauty of Hebron	0	5	10-15	50
Dibble's Russet	0	traces	5-10	40
Vermont Gold Coin	0	10-15 plants yellowing	15-20	50
Million Dollar	0	traces	10	30
Bovee	0	40 plants yellow	100	100
Davies Warrior	0	traces	traces	traces
Early Ohio	15-20	plants yellow	90	90
Dakota Red	0	traces	5-10	60
Pride of Vermont	0	0	10	30-40
Cowhorn	0	10	25-30	90
White Ohio	5-10	60-70 plants all yellow	100	100
Burbank's Russet	0	traces	5	30
White Star	0	traces	10-15	30
Triumph	50	95	100	100
Cambridge Russet	0	traces	10-15	75

The advance of the tip burn between August 13 and 23 was very great, especially on the early varieties. Irish Cobbler, Bovee, White Ohio, and Triumph were all dead and Early Rose and Early Ohio nearly so. It also made rapid progress during the week August 23-

September 1. At this date, a little early blight also appeared at one side of the plot.

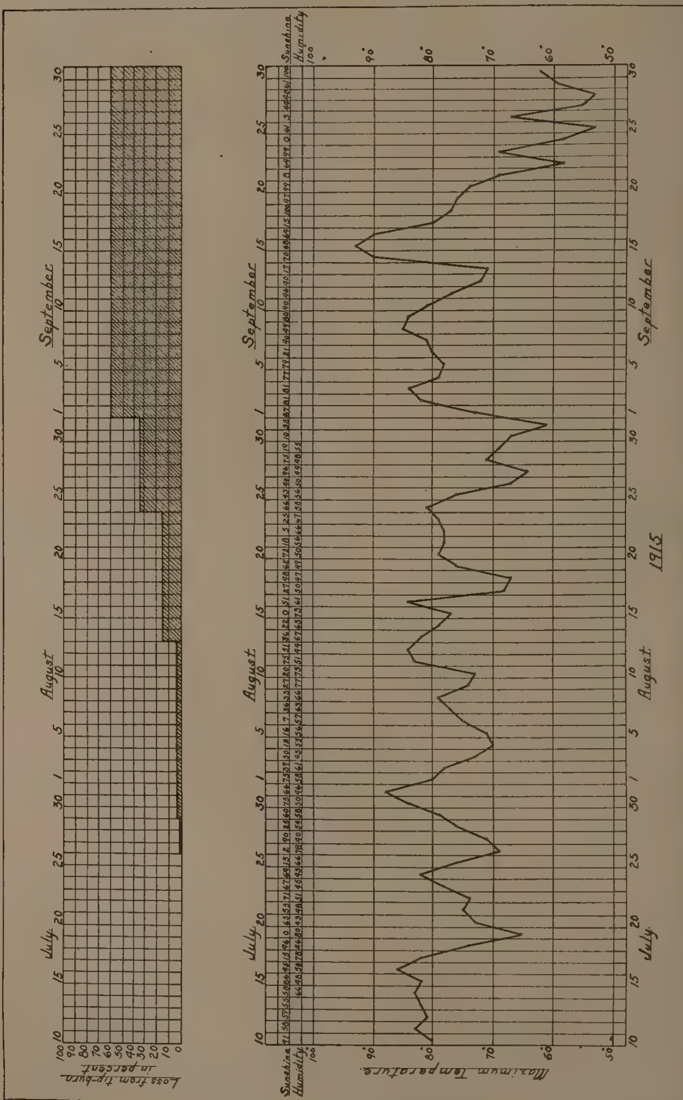

FIGURE 8.—Chart showing sunshine, humidity and maximum temperatures for 1915.

Resistance of Potato Varieties to Tip Burn in 1916

The season of 1916 was a very abnormal one (figure 9). Tip burn began to show itself at an unusually early date and the plants were practically all dead by the end of August. The first onset was noted on July 24 when Triumph had lost about 25 percent of its foliage. The very hot weather of July 20-22 was undoubtedly responsible for this situation. Hot weather and brilliant sunshine on August 7 advanced the tip burn greatly and a field of Irish Cobblers located near these plots lost a large percentage of its foliage in one day as a result of this condition. Very hot weather between August 15 to 25 completed the destruction on many of the varieties.

The following table sums up the observations:

Table IV.—resistance of potato varieties to tip burn, 1916.

Variety	Aug. 1	Aug. 11	Aug. 30
Green Mountain	traces	traces	50
Cambridge Russet	traces	traces	50
Triumph	50	90	100
White Star	20	20	100
Burbank's Russet	0	0	40
White Ohio	traces	15-20	100
Cowhorn	0	0	40
Pride of Vermont	50	50	100
Dakota Red	traces	traces	30
Early Ohio	0	0	30
Davies Warrior	0	0	5
Bovee	0	50	100
Million Dollar	traces	traces	20
Vermont Gold Coin	traces	traces	30
Dibble's Russet	traces	traces	40
Beauty of Hebron	traces	traces	20
Scab Proof	0	0	50
Early Rose	20	20	100
Norcross	0	0	50
Reading Russet	0	0	100
Sir John Llewellyn	0	0	100
Irish Cobbler	5	5	100

The varieties on which the above observations were made were planted on light sandy soil. An interesting comparison may be made between them and a nearby field of Irish Cobblers on heavy clay loam. No tip burn whatever had appeared on this latter field on August 12, while the Irish Cobblers grown on a lighter soil type were half dead. On August 30, however, the foliage on the unsprayed plants on the clay was half dead. The sprayed plants were not as severely affected. This sudden advance of the tip burn took place between August 25 and 28, when the sunshine was very brilliant, although

there was not an unusual amount of it nor was the temperature very high. On September 8, the unsprayed foliage was between two-thirds

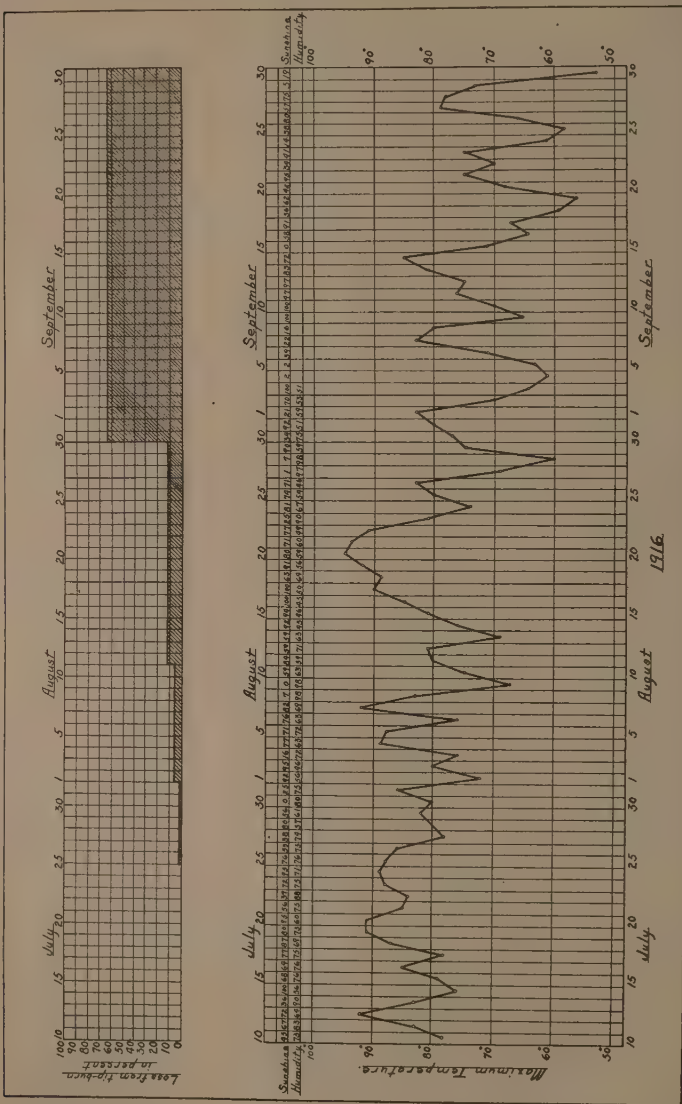

FIGURE 9.—Chart showing sunshine, humidity and maximum temperatures for 1916.

and three-fourths dead, the increase having occurred when the temper-

ature was extreme and the sunshine brilliant. During the following two weeks the plants slowly died but not as rapidly as during the hot week, and all were dead by the first of October.

The Artificial Production of Tip Burn

Field observations have made the fact clear that potato plants grown in sandy soils and in dry situations are always more subject to this trouble than those grown on clay loams or in situations where more water is available. Plants grown in the greenhouse in the spring in very dry situations, however, showed no trace of tip burn. A hot-house bed was filled with sand, a minimum amount of fertilizer applied, and humus and potatoes planted. The plants came up with slender stalks and thin leaves. One end of the bed was kept very moist while the other end was given only enough water to keep the plants just above the wilting point. These plants were grown during April and May without any tip burn appearing, although the plants at the dry end of the bed were allowed to wilt several times. The entire foliage would become flaccid and droop, but the tips of the leaves would not die. When the plants were again given water, they recovered their turgidity, but if the wilting was allowed to go on too long, the entire plant turned brown and died. Tip burn, therefore, does not seem to be a condition brought about by the general lack of water but by too small a quantity at local areas of the plant where it has been subjected to an abnormal water loss resulting from brilliant sunshine.

The failure to produce tip burn under these conditions may be ascribed to:

(1) The weaker sunlight of April and May.

(2) The immaturity of the plants.

(3) The weakening of the light by its passage through glass. Stone (15) has shown that the amount of light is reduced between 13 and 36 per cent in greenhouses. The production of tip burn on plants grown on heavy clay loams with an abundance of water will be discussed under the shading experiments described later.

This attempt at a generalized artificial production of tip burn having failed, experiments were started with a view of bringing about this condition locally. The necessary factor to introduce apparently was an excess of sunlight on a small area of the leaf. Sunlight may act either chemically to cause the destruction of important leaf constituents, e. g., chlorophyll, or it may so warm the leaf as greatly

to accelerate the loss of water. A separation of the two actions is difficult in a practical way. The concentration of the light of the sun on a particular part of the plant for a considerable period of time in itself is not easy. The separation and elimination of the heat rays from the light, chemical and other rays by passing them through a layer of water was found to be an even greater obstacle. The effect of the sun's rays on the plant is without doubt due both to the heat and the light rays, and, indeed, the others may function in this respect, but no feasible method was available for their complete separation..

The light rays were concentrated at a given point by the use of three mirrors on a heliostat. These mirrors, each about 10 by 15 cm. in size and of the best plane glass, were so arranged in frames that the light from all three could be focussed on one spot. With a little attention it was possible to keep the light from the three mirrors in one place for a half hour or more. This time doubtless is not as long as that in which the sunlight acts on the foliage during the warmer part of the day from eleven to one, but on the other hand the intensity of the light was about twice as great as that of unconcentrated sunlight. Allowing a third for the absorption of light by each of the mirrors, the light rays which impinged upon the leaf surfaces would still be about doubled in intensity. This was true of the heat rays as well as of the light rays, for a thermometer held in the spot of concentrated light registered from five to six degrees C. higher than it did when placed in the direct sunlight. In this way the intensity of the light could be increased almost three-fold since a good mirror only absorbs a small percentage of the light which falls on it. A large concave lens would have concentrated the light in a similar way but by the use of the three mirrors it was possible to turn one of them away and only utilize the light from two.

A potted potato plant was placed on a support in front of the heliostat and the particular leaves to be exposed were held in such a position that the light could be focussed on them. The exposures continued from 10 to 30 minutes, lasting usually about 15 to 20 minutes. They were made during the warmest part of the day, between ten and three. As far as possible an entire leaf or an entire large leaflet was covered, but inevitably the action of the light was very uneven. The angle at which it struck the leaflet seemed to determine the intensity of its action.

The exposure was not continued much beyond the point where pronounced wilting occurred in some portion of the leaflet. The leaflet was then marked with a tag on which the location of the most seriously affected area was indicated, and the plant was set aside until the following day. If the exposure was continued over the entire leaflet a little too long or the heat was too intense, a considerable portion of the wilted leaf died as a result; and if the area of application was limited only the margin or tip dried up.

An examination of a plant after it had been thus treated evidenced the marked similarity of this artificially produced tip burn with the natural one. The changes produced by the reflected light are much more rapid and violent but they are unquestionably of the same nature as those wrought in the field under the influence of intense midsummer sunlight. The excessive light and heat brings about so abnormal loss of water that the cells lose their turgidity to such a degree that they cannot recover. Wilting is the external evidence of this condition. The excessive heat and light also produce destructive chemical changes in the chlorophyll and it is entirely possible that these changes precede the loss of water.

The Prevention of Tip Burn

Various attempts were made to prevent tip burn on small plots of potatoes either in beds or growing in large tiles. Since tip burn is the result of the lack of water, two methods of supplying or conserving water were used, namely:

(1) To furnish to the plant roots an abundance of soil water by frequent waterings.

(2) To shade the plants during late July and early August in order to conserve as much as possible the leaf moisture and prevent excessive transpiration.

The application of an abundance of water to the roots during the heat of the summer did not avail to lessen tip burn. The plants became more succulent but tip burn attacked them about as actively as it did those growing with only the normal rainfall. The shading experiments were more successful. A heavy cheesecloth screen was stretched in the form of a tent over some 20 large tile containing the plants. An abundance of water was supplied to the roots, the foliage was succulent, the growth rank. The plants were untouched during late July and early August while the branches which escaped this pro-

tection and grew out into the open sunlight were injured to nearly the same extent as the plants in the open, which lost at least 40 percent of their foliage during early August. Clearly the protection furnished by the screen must have been of great importance in retarding the advance of this malady. Later in August, the cheesecloth screen did not cut off enough light and the foliage showed considerable tip burn although never as much as did the plants in the open.

The field prevention or, at least, lessening of tip burn by the application of bordeaux has been discussed elsewhere by the writer (10). The shading effect of bordeaux emphasized by Schander (13) would seem to play an important role in its beneficial effects on potatoes in the Middle Northern States.

The shading of tobacco by means of cloth screens in the fields, especially in the tropics, is a well established practise. It is used doubtless not so much with a view of preventing tip burn as of securing a rank leaf full of moisture, which, on drying, becomes very soft and pliable. The writer is not aware that tobacco plants suffer at all from tip burn.

WHY DO THE VERY YOUNG LEAVES AND YOUNG PLANTS ESCAPE TIP BURN?

The upright position of the youngest four or five leaves (plate I, figure 7), helps them to escape the influence of the direct rays of the sun. The concentration of cell sap is undoubtedly quite a little greater toward the growing point of the plant than it is in other portions. This can be easily verified by plasmolyzing sections from the very young leaves in potassium nitrate solution for comparison with those from the lower part of the stalk. A potassium nitrate solution of 2.5 to 3 per cent concentration will plasmolyze the cells from the lower leaves while a solution of 3 to 3.5 per cent concentration is necessary to produce this condition in the very young tip leaves. The higher osmotic pressure in these portions can also be demonstrated by cryoscopic methods.

The higher osmotic pressure also produces a marked effect on the loss of water from the tips of the plants. If both young and old leaves are removed from the plant, weighed and allowed to wilt, the latter lose much more in weight than the former.

TABLE V.

	Weight at 10:30 A. M. grams	Weight at 3:30 P. M. grams	Loss grams	Loss %
11 old leaves	35.3	21.5	13.8	39
32 young leaves	22.3	17.5	4.8	21
	Weight at 10 A. M.	Weight at 12 M.		
6 old leaves	29.3	25.0	4.3	15
25 young leaves	19.0	17.3	1.7	9
	Weight at 3:30 P. M.	Weight at 5:30 P. M.	Loss	
7 old leaves	35.5	30.3	5.2	14½
30 young leaves	20.8	18.7	2.1	9

The evaporating surface must have been very much larger in the small leaves than in the large leaves per gram of weight. This emphasizes still more the retention of the moisture by the former. The leaf injury undoubtedly is due not only to tissue scorching but also to its plasmolysis, and it is the latter which in the main is responsible for the disastrous results.

The remarkable changes which occur in the relative osmotic pressures in the various organs of the potato plant during and before the critical period when the tubers are growing have been elsewhere presented by the writer (11). During the early portion of the season the osmotic pressure is highest in the foliage of the young plants. The plants at this time are growing in size by increasing the amount of foliage. With the oncoming of the blossoming stage, however, the stalks develop the highest osmotic pressure, especially on hot dry days. The natural consequence must be that the cells of the stalk pull water from the leaves as well as from the roots. Since the leaves are already suffering from excessive transpiration the combination of losses results in tip burn. The high osmotic pressure that develops in the stalks at this time is due to their temporary storage of sucrose and of glucoses. These products are the result of the very active assimilation of the leaves in the hot sunshine, and the high pressure in the stalks is to be regarded as an entirely normal condition. On cloudy humid days, the pressure in the stalks tends to subside and a nearer approach to equilibrium becomes established as between stalk and foliage. The advance of the tip burn then stops. The plants often put out a little foliage late in the autumn. The sap of these new leaves possesses a higher osmotic pressure than that of any other part of the plant and no tip burn appears. The concentration of the cell sap is greater in the leaves of the old plants than it is in the younger ones but the difference is not enough

to prevent the leaflets from suffering from tip burn. Very old plants have a low osmotic pressure in their cell sap due to the withdrawal of sugars and salts to the tubers where they are deposited.

The color of the leaves seems to determine to some extent the liability to tip burn provided conditions become favorable. The varietal test results show that those varieties that are recorded as having yellow foliage had lost a considerable portion thereof on the date next subsequent to that on which observations as to yellowing were made. Many of the varieties yellowing in this way were of the early type and had apparently reached a certain stage of maturity. The yellow color may indicate the destruction of chlorophyll to form carotin, since many of these leaves showed very little of the green constituents of chlorophyll in solutions made from them. Ewart's (4) interesting theory would seem thus to secure some corroboration. In diffuse daylight or in illumination that is not too intense, the chlorophyll is constantly reformed as it is broken up by the action of the sunlight, so that the brilliant dark green color is maintained; but in very brilliant sunlight destructive action is more rapid than constructive action and carotin becomes the dominant constituent. The yellowing leaves are usually among the older ones so that the age of the leaf and of its chlorophyll may play some role in its ability to stand up under intense illumination.

Some exceptions have been observed. The foliage of the potato plants on very low, wet soil in 1915 was pronouncedly red, while similar plants in the same rows on higher lighter sandy soil escaped. Very hot weather a few days later affected these reddened plants much more seriously than the normal plants. The red portions of the leaflets were always the parts that died first from the tip burn.

The foliage of the majority of the varieties turned yellow when they were on the decline but Dakota Red was a pronounced exception, the foliage assuming a red tinge before succumbing to tip burn.

The tissues immediately adjacent to the brown area in tip burn is often of a yellow-green color. This seems to be an indication of an incomplete recovery from wilting combined probably with decomposition of the chlorophyll to the constituent carotin. The brown area advanced rapidly into its surrounding yellow-green zone if conditions become favorable for the increase of the dead portion.

Tip Burn on Other Plants

The foliage of the potato seems to be especially subject to the destructive action of brilliant sunlight, doubtless because of its succulence and to the fact that it has never recovered from its original tendency to grow best in shade-loving habitats. Very hot summers, however, or unusual succulence sometimes brings about similar conditions in other plants. Lettuce, both in the greenhouse and in the open air, often shows a burning or scalding of the tips of the leaves, which is undoubtedly the result of too much light and if excessive, seriously reduces market values. Certain varieties, such as Grand Rapids, are fairly resistant to this trouble. During the summer of 1915, tip burn was noted on bean (plate II, figures 2 and 3), onion and tomato (plate II, figure 1) plants growing on very light sandy soil. The tomato, although closely related to the potato and having the same type of succulent leaves, does not usually suffer from tip burn. One difference was observed in these tip-burned leaves on the tomato plants as compared with potato foliage, namely, that the affected area instead of being located on the margin of the leaflet at times was found nearer the center. Other plants are undoubtedly subject to tip burn and further search might lead to the discovery of this trouble on almost all cultivated forms.

The Breaking Down of Plants Under Stress

Tip burn illustrates an important principle in plant physiology and pathology that has not been sufficiently emphasized. This principle probably underlies most pathological physiology. Plants may grow and thrive under normal or fairly normal conditions and all of their life functions may be correlated and working smoothly. Then suddenly a few days or even a few hours of violent change may bring about the entire suspension of some one or more of these functions and greater havoc may be played in a short space of time than had been wrought by all the minor fluctuations that the plant has previously encountered. It is not the little adversities that count, because the plant usually has a chance to recover from such shocks unless they are repeated frequently and are of the same general character. Violent changes on the other hand throw the apparatus so far out of equilibrium with one sudden thrust that there is no opportunity for partial recovery and partial death results. Burns (1) has pointed out similar facts regard-

ing the tolerance of forest trees to light. Diseases resulting from the invasion of plants by fungi and bacteria to a less marked degree have their origin, also, in periods when the conditions are at their optimum in favor of parasitic attack. The breaking down of plants under stress, however, is particularly noticeable in those derangements that we class as physiological diseases.

BIBLIOGRAPHY

(1) Burns, G. P. Weather conditions and plant development. Brooklyn Bot. Gard., Mem. 1, pp. 119-122 (1918).
(2) Erwin, A. T. Tip-burn. Potato Mag., 1, pp. 8 and 34 (1919).
(3) Ewart, A. J. The action of cold and of sunlight upon aquatic plants. Ann. Bot., 12, pp, 363-397 (1898).
(4) Ewart, A. J. Function of chlorophyll. Proc. Roy. Soc. Biol. Sc., pp. 1-17 (1915).
(5) Fraser, W. P. Notes on some plant diseases. An. Rpt. Quebec Soc. Protec. of Plants, 6, pp. 45-50 (1913-1914).
(6) Galloway, B. T. Potato diseases and their treatment. U. S. Dept. Agr., Farm. Bul. 91 (1899).
(7) Goff, E. S. The tip burn of potatoes. Wis. Sta., Rpt. 13, pp. 240-243 (1896).
(8) Jones, L. R. Potato blights and fungicides. Vt. Sta., Bul. 49 (1895).
(9) Lodeman, E. G. Diseases of the potato. N. Y. (Cornell) Sta., Bul. 113, p. 306 (1896).
(10) Lutman, B. F. Some studies on bordeaux mixture. Vt. Sta., Bul. 196 (1916).
(11) Lutman, B. F. Osmotic pressures in the potato plant at various stages of growth. Am. Journ. Bot., pp. ——— (1919).
(12) Orton, W. S. Enviromental influences in the pathology of *Solanum tuberosum*. Journ. Wash. Acad. Sci., 3, pp. 180-190 (1913).
(13) Schander, R. Beitrag zur Frage über den direkten Einfluss der Kupfervitriolkalbrühe auf die gruen Blätter. Landw. Jahrb. 33, pp. 517-584 (1904).
(14) Sorauer, P. Pflanzenkreiten. (3d Ed.) Berlin (1909).
(15) Stone,G. E. The relation of light to greenhouse culture. Mass. Sta., Bul. 144 (1913).
(16) Stewart, F. C. et al. N. Y. (State) Sta., Buls. 379, 349, 338, 323, 311, 307, 290, 279, 264, 241, 221 (1915-1902).
(17) Sturgis W. C. Notes on the "early blight" of potatoes. Conn. (State) Sta., Rpt. 18, p. 129 (1894).